NATURE OF COASTAL AQUIFERS IN PARTS OF EAST COAST, ANDHRA PRADESH, INDIA

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Abstract

Coastal aquifers of Andhra Pradesh form a part of a discontinuous strip of alluvium along the East Coast of India. These aquifers comprise ridge like features generated by tidal action and the deltaic fluvial deposits. They show many of the characteristic morphological features of stream and deltaic sediments, like channel bars, levees, etc., Their maximum thickness is reported to be around 400 metres. Deltaic sediments are derived from 3 major river systems: Godavari, Krishna and Pennar and many smaller but, locally important streams. They range widely in thickness, grain size distribution and by implication in aquifer parameters and well yields which can be attributed to their depositional environment. Seasonal variation in yields of shallow wells is related to changes in the thickness of the zone of saturation. These aquifers are sustained by average normal annual rainfall is more than 1000 mm with an effective infiltration rate of 10 to 15%, and an average specific yield of around 10%. Use of groundwater continues to increase rapidly in these areas. This has resulted in up-coning of Salt water fresh water interface, but as yet there is no reversal in regional flow direction.

Aquifer chemistry shows evolution towards higher chlorides at the expense of bicarbonates and sulfates after initial rise in calcium content. Revelle’s ratio progressively decreases away from the coast. However, complexities in chemical characteristics of the aquifers are introduced on four counts: 1. saline water ingress in locally over-exploited areas, 2. cyclonic activity that transports large quantities of sea water directly over land, 3. over-exploitation and 4. industrial contamination. Further, deviations in expected trends are introduced by geomorphic characteristics of the terrain, aquifer geometry, basement characteristics, etc. Thus northern part of the coast being devoid of wide alluvium is hardly effected by saline ingress. But, vast tracts of Aqua-culture along alluvial coast in the southern part of the area has rapidly effected the shallow unconfined aquifers. Protection measures are controlled abstraction rates, proper designing of wells, artificial recharge and drainage, remedial pumping, etc.

Introduction

The coastal area is known for wet cultivation mainly by surface water irrigation with groundwater as supplementary source. Increasing trend of pollutants in this area is a major threat for drinking, domestic and irrigation purposes. In
order to study and to delineate the contamination levels caused by these factors, groundwater quality studies have been caused all along the coastal tract of Andhra Pradesh. Water samples are collected from observation wells established by Ground Water Department and other private wells for different seasons are subjected to chemical analyses. Geochemical methods are applied in this study to find out both lateral and vertical extension of the contamination.

Identification of fresh-saline water interface has been attempted by analyzing water samples collected from different aquifers to study chlorine/bicarbonate ratio (Ghyben-Herzberg relationship). The studies revealed that the salt water contamination has moved inland at vulnerable places. Development of groundwater resources has further disturbed the isostacy resulting interface moving inland. The cyclonic storms repeated at intervals created havoc in the coastal areas causing vast agriculture areas sand casted and submerged under sea water resulted in major damage to groundwater aquifers.

**Purpose and Scope**

The development of groundwater resources in coastal area is a delicate issue, and careful management is required if water quality degradation due to the encroachment and seawater is to be avoided. In many cases, difficulties arise when aquifers are pumped beyond their natural recharge rate and seawater is drawn into the system to maintain the regional groundwater balance. (Howard, 1987). Problems can also occur when excessive pumping at individual wells which lowers the potentiometric surface on a localized scale and causes upcoming of the natural interface between fresh and saline water.

Coastal aquifers are also sensitive to sea level changes, such as postulated rises due to global warming. The associated volumetric expansion of sea water and melting of snow caps would increase the extent of sea water intrusion and reduce the availability of fresh groundwater resources. In this respect areas with low elevation are particularly vulnerable.

Many models have been developed to represent and study the problem of sea water intrusion. They ranges from relatively simple analytical solutions to complex numerical models.

**Hydrogeological Framework**

Nearly eighty percent of the shore area is occupied by river and coastal alluvium and the remaining is underlain by Archaean group of rocks.

The geological succession of the rock formations along the coast in the State is as follows:(Plate-I)
<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>River and coastal alluvium</td>
</tr>
<tr>
<td>Sub-Recent</td>
<td>Laterites</td>
</tr>
<tr>
<td>Eocene</td>
<td>Basalts</td>
</tr>
<tr>
<td>Upper Jurassic</td>
<td>Gondwanas</td>
</tr>
<tr>
<td>Archaean</td>
<td>Khondalite suit of rocks Charnockites</td>
</tr>
<tr>
<td></td>
<td>Granites and gneisses</td>
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</tbody>
</table>

Gondwanas: Isolated out crops comprising of sand stones occur near Prathipadu in East Godavari district, Ranastala in Srikakulam district, Elamanchili area in Vizaq district and Tenali in Guntur district. These sand stones are light coloured clayey and fine to course grained and exhibit mottle appearance. Some horizons are pebbly and Carbonaceous. The attitude of sandstone beds is variable with easterly to NE-SW strike with dips ranging from 6° to 12° but occasionally near 20° towards south.

Sub-recent deposits: Laterites occurs as thin layer over the weathered Kondalites, granites and gneisses in and around Vizaq and Bhimili areas of Vizaq District, Mandara and Uddanam in Srikakulam district, Kavali in Nellore district and thickness of laterites capping vary from a few metres to 30 metres tapped by shallow dugwells yielding capacities up to 50,000 lpd.

Recent deposits: These consists of river and coastal alluvium comprises of silts, sand and gravel deposited by rivers during floods and is confined essentially along the streams courses in the interior and to individual alluvial fans along the sea coast at many places in Sompet and Ichapuram taluks. The river alluvium is covered by a Veneer of sands along the coast. The widest patch of alluvium is seen in the Krishna-Godavari delta region extending over 30 Kms.

The coastal and deltaic alluvium is mostly found along the entire coastal belt in the shore areas as Vest plains extending even beyond 30 km; thickness ranging between 50 to 500 m. as seen in Guntur, Krishna, West Godavari and East Godavari districts. In Prakasam, Visakhapatnam and Srikakulam districts the coastal alluvium is restricted to narrow belt along the shore mainly tapped by means of filterpoints/shallow tubewells with yield ranging between 40,000 to 70,000 lph.

Dynamic satellite data for two seasons indicate that there is no change in cropped area and hence, groundwater draft is more or less constant. But well yields show significant changes across the area. Sinuous tracts of alluvium laid down by rivers system exhibit well marked and predictable changes in the grain size, sorting and thickness. Thus, at the concave bends the material is coarse, ill sorted and not very thick. At convex bends the alluvium is finer well sorted and thicker. These pockets could be located with IRS data and statistically significant difference in discharge of wells is noted in these two pockets. Although the wells located in concave bends tend to reach recharge boundary
Geomorphological features.

The geomorphological disposition of coastal areas of Andhra Pradesh was prepared by visual interpretation of landsat imagery and IRS-IC imagery and the various units are discussed below.

Emergent Coastal plain: Forming the inland boundary and running parallel to the shore is the emergent coastal plain whose width varies from 5 to 40 Km. It is characterized by a moderate fluvial activity and occurrence of lakes, tanks and abandoned marshes etc. The material comprises of sandy, loamy and clays. At places saline soil patches can be expected.

Deltas: Deltas of major rivers along the coast form an important land form. These deltas are laid down by the rivers Krishna, Godavari and Pennar which have several paleochannels which are important prolific groundwater yielders.

Tidal flats: These are the depressions either at the back of beach sand ridges or in between beach sand ridge complexes. They get submerged under marine water. They represent two types 1) tidal mud flats and 2) tidal sand flats both are saline in nature. Tidal mud flats are mostly submerged under brackish water and comprise of unconsolidated fluviomatric and organic material. Tidal sand flats are located at the inner peripheries of mud flats or at the elevated areas within mud stretches. They get submerged under brackish water periodically and are mostly sandy brackish stretches.

Beach and beach ridges: Along the above line there is an active beach (3) whose width varies from place to place. It comprises of loose sand and single material. The beach ridges are (i) complex of recent origin and comprises of ridges and swales forming an alternate sequence of high and low ground. (ii) old beach ridges and swale complex. The elevated ridges comprise of loose sand and silt where as the low depressions called swales comprise clayey silt and mud. The swales are not suitable for Groundwater development as they are mostly saline due to submergence of tidal water.

Cyclones and Their Effects

On 8th November, 1996 severe cyclonic storm crossed the coast at East Godavari District with gale speed of 200 to 250 Kms and caused havoc in coastal areas of the district. These natural calamities are not new to Andhra Pradesh.

Analysis of 16 cyclones occurs over a period of 317 years, one in the 17th century, 4 in the 18th century; 3 in 19th century and 8 in 20th century indicates that there is an increase in their numbers during the 20th century. This is due to
ecological imbalances created by unscientific development of resources, deforestation, soil erosion, silting and development of mangroves in major and minor irrigation tanks and its distributary drain, spreading of saline water over the land surface during cyclone, high tides in lacustrian rivers resulting in contaminating fresh water aquifers present in the coastal areas.

Salinity inflow in Estuaries: The tidal fluctuation is accompanied by a cyclic diurnal change in water quality due to the mixing, in continuously varying proportions, of original river water with sea water. In the lower reaches of rivers, the water quality resembles that of sea water and at the farthest point inland as that of primary river water. Within the tidal reach, the changes in water quality depends on the composition of the original river water and sea water. As the zone of mixing and diffusion migrates up and down the river, the maximum contamination occurs during high tides and the minimum during low tides. During the lean months when the river stage is at its lowest, the quality is most adversely affected by tides, due to the predominance of sea water.

Zone of diffusion: The interface is, therefore a transitional zone and not one of sharp contact. Groundwater extraction changes the dynamic balance between the flow of fresh water and the interface so that the interface will move and attain an equilibrium position governed by the quantity attracted and the balance out flow of fresh water to the sea. Heavy pumping of groundwater through filter points, in coastal areas, during lean months is causing contamination.

Quality of water:

Chemical analysis forms the basis of interpretation of the quality of water in relation to source, geology, climate and use. Water being an excellent solvent, it is important to know the geochemistry of the dissolved solid constituents and methods of reporting analytical data. The contamination of fresh water aquifer due to sea water ingress is estimated by the study of chloride-bicarbonate ratio and EC of water samples collected from wells for 1984 and 1994.

Based on the chemical analysis data, the chloride-bicarbonate ratio has been demarcated and ratio contour generally runs parallel to sea coast with major bends with the mainland south of Nellore, Ongole, Repalle, Eluru and Kakinada and towards sea coast at the mouths of Pennar, Krishna and Godavari rivers. Specific conductance contours of 1000 microsiemens/cm for the years 1984 and 1994 almost concur with that of Chloride- Bicarbonate ratio contours. At southwest of Nellore, Ongole, Repalle, Kaikaluru areas contamination advances inland due to over development of groundwater, cyclonic storms and man made pollution through aquaculture ponds and industries. The remaining areas has no significant change. These trends indicate effects of estuarine rivers and saline water ingress into fresh water in the areas other than deltaic mouths. Surveys
carried out by the department in the Krishna-Godavari delta indicated that 50% of the area is identified as salt water zone. Large scale sea water intrusion has taken place in the southern part of Chirala, Bapatla, Repalle and Tenali taluks of Guntur district, Divi, Gudivada, Bandar, Kaikalur areas in Krishna District, Bhimavaram, Narasapuram areas and southern part of Eluru and Tadepalligudem in West Godavari District. The contamination may be attributed to the repeated marine transgressions and incursions to which the area has been subjected to in the past.

The analysis of water level data of 28 observation wells in the coastal alluvium located close to the coast and topographic elevations less than 5 metres above mean sea level indicate that the water levels are high and above mean sea levels by about 0.20 to 3.00 m. except in 5 wells in East Godavari district (Karapa, Katrenikona, Allavaram, Kotanandur, Sakhenelipalli) and two locations in Krishna district (avanigadda, Nagayalanka). When the water level falls below the mean sea level by a maximum of about 2.00 m. the high fresh water table above mean sea level as per Ghyben-Herzberg’s theory helps to keep the sea water inter-face (below the operational depth of groundwater exploitation in the area to) near vulnerable range to much below the operational depth of exploitation. However even in parts of these areas the quality if found to be contaminated by cyclones, tidal effects, poor drainage, waterlogging conditions and agro based industries. The water levels below mean sea level disturbs the interface and may bring in the sea water interface with in the operational depth of groundwater exploitation in the area.

**Groundwater Quality Near Aquaculture Ponds**

To study effects of aquaculture ponds 120 observation wells were established to monitor groundwater levels and quality of water periodically. Water samples collected near ponds indicate high specific conductance values between 770 to 25000 microsiemens/cm. Out of 120 samples 85 samples show high specific conductance values and 35 samples are in permissible limits. This clearly shows the contamination of groundwater by aquaculture activity in the coastal areas of Andhra Pradesh.

**Conclusions and Recommendations**

In the 633 shore area villages of the State the main source of drinking water is by means of shallow wells as the deeper aquifers are saline due to ingress of salt water. The river alluvium deposited by Krishna, Godavari and Pennar rivers near the coast are more prolific groundwater aquifers.

Deltas, sub-deltas, sand bars, paleo river channels are potential groundwater units, shallow dugwells feasible down to depth of 3 to 6 m.
Exploration carried out by various organization indicates that fresh water is limited to shallow depths near the Coast. Tubewells constructed away from the coast did not suffer in quality and the yields are even up to 1 cusec in the delta regions. The fresh water aquifers occurs down to 85 m. below which saline water occurs.

As per Ghyben-Herzberg theory the sea water interface near coast is near valunerable range to much below the operational depth of exploitation of groundwater. However, contamination of fresh water aquifers is noticed in certain parts of these zones due to cyclonic storms, tidal effects, agro based industries, waterlogging conditions and poor drainage system.

Chemical quality of the water analyzed indicated that there is no major change in the quality of water along the shore areas except in Kaikalur, Bandar and Divi areas of Krishna district; Bapatla, Tenali and Repalle areas of Guntur district; Bhimavaram, Tanuku and Tadepalligudem of West Godavari district; where the quality of fresh water aquifers has deteriorated due to cyclones, poor drainage system and waterlogging conditions. Due to over pumping of groundwater and subsequent disturbance of equilibrium of fresh water and salt water interface, fresh water aquifers in parts of Nellore and Guntur districts are becoming saline.

The present development of groundwater along the shore areas is limited and is mainly used for drinking as well as supplementary irrigation. The percentage of development is more than 23 per cent in Pennar delta region of Nellore district and it is less than 10% in the remaining districts.

Contamination has advanced towards inland between areas of Godavari, Krishna and Pennar river and less advancement at mouths of river deltas due dilution of salt water by river waters.

Further, contamination of fresh water shallow aquifers near aqua culture activity is noticed along the coastal areas, is alarming and has to be regulated with Legislation.

Preventive measures have to be initiated by adopting.

- Regularization of groundwater development in critical areas with Legislation.

- establishment on scientific lines of piezometer network along the shore areas and monitor water levels and quality periodically to study the effects and extent of sea water intrusion inland and demarcate the fresh-salt water interface time to time.
-study the different methods of preventing salt water intrusion inland by structural barriers and artificial recharge of groundwater already in vogue in the coastal areas elsewhere in the country.

- study of the extent of ingress of tidal waves through the drains and rivers and identify sites for construction of structural barriers to prevent sea-water ingress inland.

- Carry out soil survey and existing cropping pattern studies to suggest salt resistant cropping pattern.

References


- Report of the working group on groundwater resources in the shore areas of Andhra Pradesh - Ground Water Department - 1985.


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